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EFFECTS OF LIQUID VISCOSITY ON TLD PERFORMANCE -- EXPERIMENT AND SIMULATION--

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INTRODUCTION Among the design parameters of TLD (Tuned Liquid Damper), liquid viscosity significantly affects the effectiveness of TLD at relative small amplitude of oscillation. A nonlinear model for TLD has been proposed by the authors [Ref.1], originally for low-viscosity liquid. The validity of the model for TLD with highly viscous liquid is verified by shaking table experiment. The effects of liquid viscosity on TLD performance are subsequently discussed on the basis of TLD-structure interaction simulations. The TLD tank used is a rectangular container (59.0cm long, 33.5cm wide and 40.0cm high) and is filled with H=3.0cm depth liquid, corresponding to a natural frequency fw=0.458 Hz.

NONLINEAR MODEL AND ITS VALIDITY FOR HIGH VISCOUS LIQUID The shaking table experiment uses the same set-up as Ref.1 except for liquid viscosity. The TLD is excited sinusoidally parallel to the 59cm direction of the tank. For three excitation amplitudes, A=0.2cm, 0.5cm and 1.0cm, the excitation frequency f is varied in the range of $0.8<f/fw<1.2$. The viscosities ν of liquid used are $11.2\nu_w$ and $30.0\nu_w$, where $\nu_w=0.01cm^2/s$, the viscosity of water. The wave surface elevation near the end wall of TLD container and the base shear force of TLD due to liquid motion (inertia force of TLD tank is cancelled) are measured.

As an example, experimental results and theoretical simulations for the case of A=0.5cm are compared in Fig. 1. η_{max} and η_{min} are the maximum and minimum values of wave elevation, and F is the amplitude of base shear force. These are nondimensionalized with respect to liquid depth H, and inertia force of liquid (as a

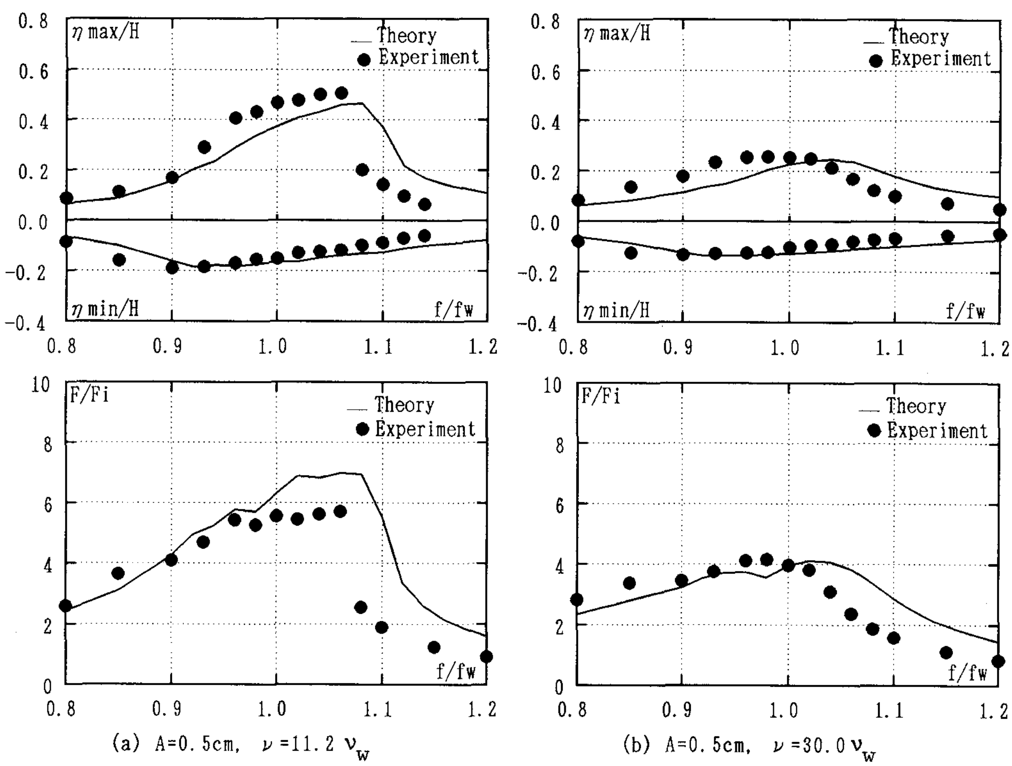

Fig.1 Frequency response of wave surface elevation and base shear force of TLD

solid mass) F_i, respectively. Between experiments and theoretical simulations, there is some discrepancy in the resonance frequency, but overall agreement is good (Fig.1). From all the experiment cases, it appears that the model can well predict the motion of even high viscosity liquid ($\nu=30\nu_w$) until breaking wave occurs.

TLD-STRUCTURE INTERACTION AND VISCOSITY EFFECTS Consider a SDOF structure (f_s=0.458Hz, ξ_s=3.2%) subjected to a external force Fe=Fosin(2πft) (Fo is constant) and its resonance amplitude without damper is assumed to be 1.0cm. Effect of TLD with various liquid viscosity is herein studied by the TLD-Structure Interaction model (Fig.2). This nonlinear model has been verified experimentally in Ref.1, for TLD using water. The model is now expected to be valid as well with more viscous liquid, under the limiting condition discussed in the previous section. Numerical simulations of structural response with and without TLD are shown in Fig.3. The liquid mass in TLD is 1% of the structure.

TLDs with liquid viscosity ν_w, $5\nu_w$ and $20\nu_w$, respectively, are used in simulation. In all these cases, the maximum structural response decreases to less than 0.12cm after installing TLD. With low-viscosity liquid (ν_w), the frequency response curve has several local peaks and there are two higher peaks around f/fw=0.95 and 1.05. Increasing liquid viscosity to $5\nu_w$, the local peak values of response curve come down and the value at f/fw=1.00 increases. Then the response curve becomes a one-peak curve when ν is further increased to $20\nu_w$. On the condition that the local peak value of response curve is smallest, the liquid viscosity has an optimal value at about $5\nu_w$ for this example.

The TLD with optimum viscosity as found above, is compared with a TMD whose parameters for mass ratio of 1% are optimized [Ref.2] at damping ratio ξ_{TMD}=6.1% and tuning ratio f_{TMD}/f_s=0.99. As Fig.4 shows, the TLD and TMD, when both optimized, have comparable effectiveness.

REMARKS Under the continuous free surface (no breaking wave) condition, the nonlinear model for liquid motion previously proposed by the authors, is valid to a fair extent even for high-viscosity liquid ($30\nu_w$). Wave height in TLD is decreased as liquid viscosity increases, for the same excitation amplitude. The damping of liquid motion can be varied by changing liquid viscosity; an optimal liquid viscosity exists that makes the effectiveness of TLD almost the same as TMD.

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REFERENCES

[1] Fujino,Y. et.al., J. of Str. Engg. JSCE, 35A, 561-574, 1989.(In Japanese).
[2] Warburton,G.B. et.al., Earthq. Engg. & Str. Dyn., 8, 197-217, 1980.

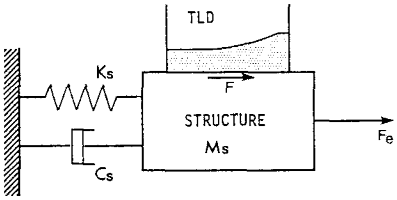

Fig.2 TLD-Structure Interaction model

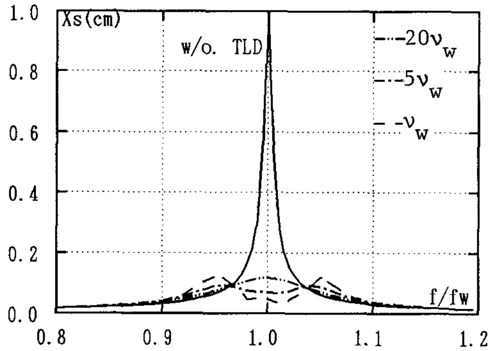

Fig. 3 The response of structure with TLD

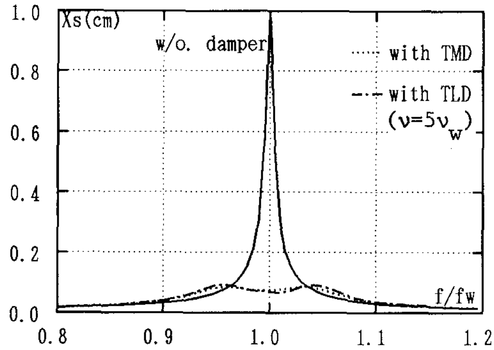

Fig. 4 Comparison of TLD and TMD